THEORETICAL SUBSTANTIATION OF TOPPING PARAMETERS WITHOUT SUGAR BEET HEAD COPYING

ТЕОРЕТИЧЕСКОЕ ОБОСНОВАНИЕ ПАРАМЕТРОВ СРЕЗА БОТВЫ САХАРНОЙ СВЕКЛЫ С ГОЛОВОК КОРНЕПЛОДОВ БЕЗ ИХ КОПИРОВАНИЯ

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Abstract: *Nowadays topper machines which cut beet tops without copying root heads via rotary topper and only after this heads are cuts individually by passive knife widely used in the world. However, with using this topping method significantly increases sugar-bearing plant material losses. Taking into account that sugar beet tops is effective raw material for receiving biogas, its collecting without loss is actual beet industry problem. However, when cutting tops from sugar beet heads with individual copying and collecting tops from each root crop head the topper productivity is significantly reduced, the design of the topping device becomes complicated, operational expenses considerably increase. Methods of mathematical modeling, programming and calculations on PC are used in the course of research. As a result of the conducted research the mathematical model of a cut without individual copying of root crop heads as well as algorithm are developed. This algorithm enables to determine the rational height of installation of the cutting device over the level of soil surface that in this turn provides minimum losses of beet tops. Dependence of sugar-bearing plant material losses and residues of beet tops on cut height without individual copying of root crops heads was experimentally defined. Comparison with theoretical calculations showed that in the range of working heights of a cut of 20-60 mm deviation does not exceed 1%.*
KEYWORDS: SUGAR BEET, ROOT CROP HEADS, TOPS, MATHEMATICAL MODEL, CUT WITHOUT COPYING.

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1. Introduction

Currently the toppers carrying out beet tops cutting without individual copying of root crops heads are widely spread in the world. This is due to the fact that the modern industrial production technology of sugar beet suggests that at the harvesting time sugar beet heads are the same size and shape and also they located at same level above the soil surface. However, studies found that these circumstances are not always observed, even at careful compliance of all modern technologies requirements. Natural factors, which occur even in the most favorable areas of cultivation of sugar beet presuppose: various size and shape of root crops heads; different shape and height of the tops bunch; obligatory presence of dry and laid tops (which during the growing season certainly appear) and various arrangement of heads above level of the soil surface.

When accurately trace the global development of harvesting mechanization of beet tops, then it can be seen what mechanized process of cutting the tops inside sugar beet harvester was replaced on individual copying of each head of root crop in a row and their topping on a root. However, reducing the cleaning performance, the complexity of the designs, significant operating costs have led to the fact that the individual copying of root crops heads during topping process has been substituted by cutting without copier, despite the obvious and significant losses of sugar-bearing mass and tops.

Furthermore, modern toppers which carry out a cutting without copying are not always adjust on a optimum working height for cutting unit. These units mostly have working body of rotary type [1]. Adjusting the topper on the desired cutting height is done by visual assessment of the cut tops quality. This can lead to unreasonable losses of sugar-bearing mass or to increasing tops residues on root crops heads. Moreover, after setting the desired cutting height, typically adjustment of its value in most cases is not done.

At this time, there are no methods for determining rational height of cutting tops without copier, which would be based on the losses sugar-bearing mass and residues of uncut tops meeting established requirements.

In general, this fact is a significant problem for beet industry, since reducing the losses of sugar-bearing mass at the cut directly reduces losses but at the same time increases the content of tops that being to reducing of sugar yield when processing.

2. Preconditions and means for resolving the problem

2.1. Analysis of recent research and publications

Such researchers as A.O. Vasilenko, P.F. Volk, V.M. Bulgakov, N.M. Zuev, L.V. Pogorelyiy, N.V. Tatyanko, N.M. Boris et al. found a linear dependency found that between heads height above the soil surface and dimensional characteristics of root crops.

2.2. Purpose of the study

Finding opportunities for effective cutting without copier of sugar beet tops with minimal losses.

2.3 Materials and Methods

Methods of mathematical modeling, programming and calculations on PC are used in research.

3. Results and discussion

To reduce the sugar-bearing mass losses it is necessary to develop a method for determining the rational height of cutting without copier of beet tops from root crop heads. To solve this problem a mathematical model of the cutting without copier process was used [2]. Dependences of sugar-bearing mass losses and the tops residues on root crops from height of cutting without copier will be determined theoretically as well as experimental verification of the obtained results will be carried out .

The model of the head of root crops of sugar beet, which can be approximated by a conically shaped body was developed (Fig. 1). Main geometric parameters of the root crop head are shown in Fig. 1.

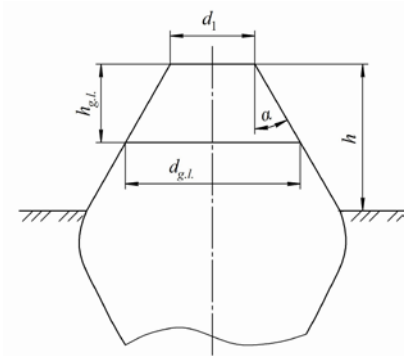

Fig. 1. *Model of sugar beet head*

Using simple geometric dependencies between parameters of sugar beet head and tops following dependencies were developed:

$$\left.\begin{aligned} h_{g.l.} &= a\,h + b, \\ d_1 &= m\,h + n, \\ d_{g.l.} &= d_1 + 2\,h_{g.l.} \cdot tg\alpha. \end{aligned}\right\} \qquad (1)$$

where: $h_{a.l.}$ – distance from the upper part of the head to the bottom of green leaf area; h – head height above the soil surface; d_1 – diameter of the upper part of the root crop; $d_{g.l.}$ – diameter of tops bunch; α – cone slope of root crop head; a, b, m, n – constants.

Six groups of heads arrangement of sugar beet roots and tops with respect to the soil surface were distinguished (Fig. 2).

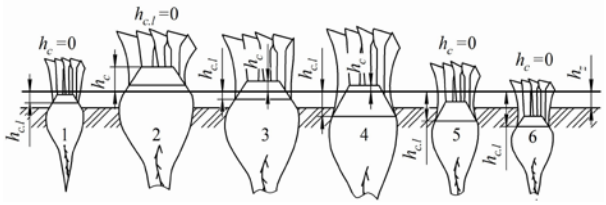

Fig. 2. *Characteristic cases of root crops and tops arrangement: height of cut tops ($h_{c.l}$) and root crop heads (h_c)*

Sugar-bearing mass losses and tops residues of root crops of the given interval of head height above ground are determined by the following formula:

$$M_i = F\left(h_i;h_c\right)\cdot P\left(h_i;h_{i+1}\right)\cdot N_i, \qquad (2)$$

where: $F(h_i;h_c)$ – sugar-bearing mass losses and tops residues of root crops:

– for root crops heads:

$$F(h_i;h_c) = V_b \cdot \rho, \qquad (3)$$

– for beet tops:

$$F_l(h_i;h_{c.l}) = V_l \cdot \rho_l, \qquad (4)$$

where: V_b , ρ and V_l , ρ_l – accordingly volume and density of root crops and beet tops; N_i – amount of root crops of given interval per unit area; $P(h_i;h_{i+1})$ – probability of given interval of the height above ground heads of root crops is defined by the formula:

$$P\left(h_i;h_{i+1}\right) = \frac{1}{\sigma\sqrt{2\pi}}\int_{h_i}^{h_i+1}\exp\left(-\frac{\left(h-m\right)^2}{2\sigma^2}\right)dh\,. \qquad (5)$$

The integral in (5) is not determined in quadratures, therefore the appearance probability of root crops of given interval of height above ground defines the numerical integration by Simpson's formula. Summing tops residues and sugar-bearing mass losses for all intervals of heights above ground, obtained the total tops residues and sugar-bearing mass losses per unit of area:

$$BM = \sum_{i=a}^{b}\left[N\cdot F\left(\frac{h_i+h_{i+1}}{2};h_c\right)\cdot\left(\frac{h_{i+1}-h_i}{3m}\sum_{j=0}^{m}c_j\cdot f(h)\right)\right], \qquad (6)$$

$$GM = \sum_{i=a}^{b}\left[N\cdot F_l\left(\frac{h_i+h_{i+1}}{2};h_{c.l}\right)\cdot\left(\frac{h_{i+1}-h_i}{3m}\sum_{j=0}^{m}c_j\cdot f(h)\right)\right], \qquad (7)$$

where: m – intervals amount: $m = 2U$; U = 1, 2, 3, 4,...; c_i – coefficient at the values of integrand in the corresponding points, c_j = 1, 2, 3, 4, 2, 4,…, 2, 4, 1.

On the basis of the following dependencies algorithm and calculation program for the PC were developed. The calculation of losses sugar-bearing mass and tops residues depending on the height of cutting without copier under appropriate agrophisical conditions and root crops characteristics are given at Fig. 3.

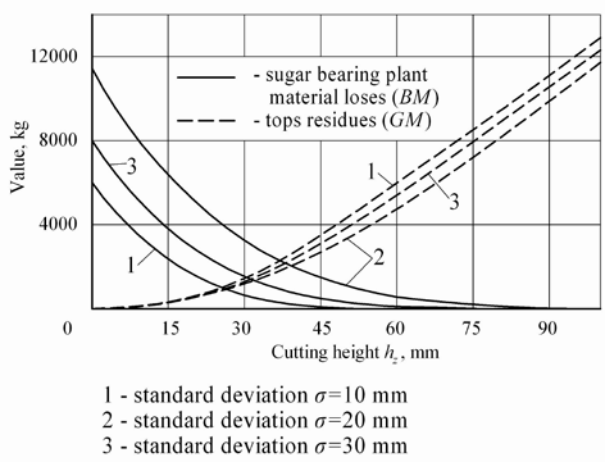

Fig. 3. *Dependencies for finding cutting height without copier at expectation value m = 40 mm*

To verify the mathematical model of experimental studies has been conducted. At the same time certain base characteristics of sugar beet and sugar beet fields under these studies were defined, are presented in Table. 1.

Table 1. *Data for defining sugar-bearing mass losses and tops residues*

Indicators	Value of indicators or functional dependence
Yield, t·ha^{-1}	50,5
Characteristics of distribution of root crops heads height above ground: expectation value, mm standard deviation, mm	 55,4 16,9
Average corner value of root crop head conicity, degree	78
Diameter of the upper part of a head, d_1	$d_1 = 0{,}58h + 14{,}2$
Height of a zone of green leaves, $h_{g.l.}$	$h_{g.l.} = 1{,}02h + 11$

The results of the comparison of theoretical and experimental studies are shown (Fig. 4).

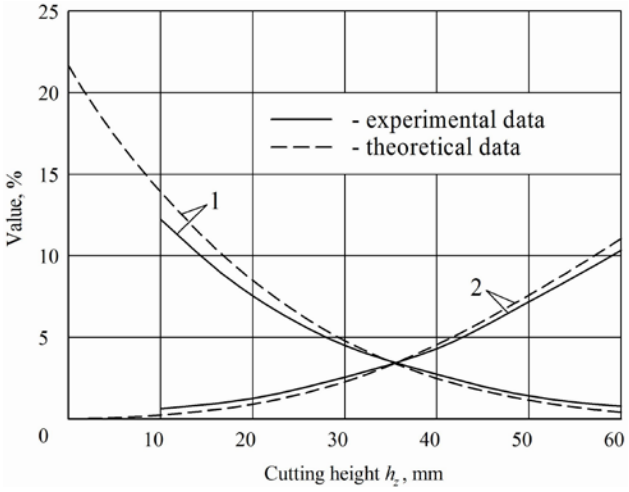

Fig. 4. *Dependence of sugar-bearing plant material losses (1) and tops residues (2) on the height cutting without copier h_z*

Defining of the quality indicators was conducted by well-known methodology. This methodology is relatively precise but is labor-consuming that limits the number of experiments.

Theoretical calculations are compared with experimental studies (Table 2) deviate as follows:

– sugar-bearing plant material losses – from -0,3% to +1,8%;

– tops residues from -0,3% to 0,7%.

Table 2. *The absolute deviation of the theoretical calculations results and experimental data*

h_z, mm	10	20	30	40	50	60
Sugar-bearing plant material losses, %	1,8	0,9	0,3	-0,2	-0,2	-0,3
Tops residues, %	-0,3	-0,2	-0,2	0,3	0,4	0,7

One of the reasons for deviation of the results of theoretical and experimental studies is not taken into account in the mathematical model of the additional tops cleaning and root crops damage of inside sugar beet harvesting machine.

When the sugar-bearing plant material losses make up from 1% to 5%, which are close to the agro-technical requirements, the deviation of the results of theoretical and experimental studies does not exceed 0.7% for the tops residues and 0.5% for the sugar-bearing plant material losses.

Comparing the results of experimental and theoretical studies, we can conclude that the theoretical model with sufficient accuracy displays trends dependency sugar-bearing plant material losses and tops residues from the height of cutting without copier. Therefore, this mathematical model can be used to predict the sugar-bearing plant material losses and tops residues of different varieties of sugar beet. Using these dependencies that are shown in Fig. 3 it is possible to determine the height of cutting without copier with predictable losses on sugar-bearing plant material and residues of the tops.

4. Conclusion

1. Model of sugar beet head and mathematical model of sugar-bearing plant material losses and tops residues when cutting without copier depending on the setting of the cutting height was developed.

2. Numerical simulation on the PC allowed to calculate of sugar-bearing plant material losses and tops residues depending on the height of cutting without copier under appropriate agrophysical characteristics of field and sugar beet roots.

3. Comparing the results of theoretical and experimental studies have established that discrepancy of sugar-bearing mass losses and tops residues do not exceed 1 ... 2%, which is fully correspond with the methodology of research and used in research experimental devices.

4. The proposed mathematical model can be used to predict the sugar-bearing plant material losses and tops residues under different varieties of sugar beet cultivation, harvesting techniques and tools to predict the quality indicators of cleaning.

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